BUILDING SHELL, INTERIORS, & FURNISHINGS SUB-SYSTEMS

INTRODUCTION CO_2 BALANCING WITHIN MATERIALS SPECIFICATIONS

INTRODUCTION

This CO_2 balancing report using the specification of materials as the sole procedure for balancing is somewhat limited in scope at this time due to the specifics of the new design still being determined. The approach taken therefore is to refine and organize the technique previously reported on so that there is better understanding of methods and therefore more possibility of implementation. A follow up report will contain actual figures relative to the new building.

CO_2 Balancing: Necessary protocols

One goal of the UT Houston Health Science Center project was to respond at a local scale to the Kyoto Protocol by utilizing renewable materials that are potentially net sinks of carbon. Namely, if the carbon from CO_2 "stored" in some building materials is equal to or greater than the total carbon released as CO_2 during the upstream life cycle stages of other materials. When this is accomplished, assuming a certain longevity for the material, then the materials (ideally) may have “zero impact” on global CO_2 warming during their useful life. To ensure success in carrying out CO_2 balance within material specification certain protocols need to be followed that enabled this procedure to be carried out successfully. These protocols are the following:

1) Develop a baseline condition using national and regional data that describes the hierarchy of impact in CSI or Uniformate terms so that work is directed where the most imbalance presently exists.

2) Use a building design approach at whatever scale that fits into the CIB International Protocol on Open Building Systems (see CIB in bibliography) so that there is a clear differentiation between infill and structure.

3) That each system become reusable through easily accomplished diss-assembly and reassembly procedures other wize the CO_2 balancing might be a false premise over time

4) That the building is divided into identifiable scalar entities which could potentially be clearly balanced within themselves

5) That module sizes of components be determined to coordinated to other parts of other subsystem (e.g. wall to floor to ceiling to furniture

6) That sizes and weights of components be designed for the potential for human interaction and alteration which influences how many supports are required

7) That there is a high degree of recycled and locally sourced components thus reducing the amount of CO2 impact to be balanced from the start.

8) that of those materials that are termed natural are not necessarily higher in CO2 sequestering due to their actual upstream impacts

BACKGROUND

As in most industrialized countries, by volume, the most significant greenhouse gas emitted in the U.S. is carbon dioxide (CO_2), accounting for 82-84% of the total global warming potential of all U. S. GHG emissions. Greater than 98% of all U.S. emissions of CO_2 originate from the combustion of fossil fuels such as coal, petroleum, and natural gas. Fossil fuel combustion emissions are determined by three factors: a) energy-consuming processes and services, b) their energy intensity (i.e., the amount of energy used for each process or service), and c) the carbon intensity of the fossil fuel energy source (i.e., the amount of carbon dioxide released per unit of fuel used). Less than 2% of U.S. CO_2 emissions are caused by non-combustion industrial processes such as chemical reactions occurring during cement manufacture, soda ash manufacture and consumption, and aluminum production.Fossil fuel combustion sources of CO_2 emissions can be divided into four energy end-use sectors: transportation, industrial residential, and commercial. Each sector's share of total 1997 U.S. CO_2 emissions is shown in Figure 1. For all the sectors except transportation, a substantial portion of energy-related CO_2 emissions result from the consumption of electricity (including losses).

To date, most efforts to reduce GHG emissions during a building's useful life are focused on the energy consumption required to operate and maintain a building. Numerous energy efficiency measures that significantly reduce energy consumption during a building's use, operation, and maintenance (e.g., energy-efficient lighting) have been accepted and implemented by some design professionals and the some of the building industry. However, the use phase represents only one chapter in the building life-cycle story. The upstream phase of processing and manufacturing building materials and products causes enormous off-site impacts prior to the building's use. It was evident that the practices of the building design and construction industry play a significant role in releasing GHGs, especially CO_2 emissions. With a potential crisis fast approaching and the likelihood of environmental impact methods being imposed through legislation and regulation, now is the time for the building industry professionals to become leaders rather than followers in developing new approaches to the design of the built environment.

The industrial sector of the U.S. economy accounts for about one-third of national end-use CO_2 emissions with manufacturing activities accounting for the largest share of the sector. Aside from electric utilities, whose purpose it is to produce electric power for the rest of the economy, the top-ranked manufacturing industry of the industrial sector in terms of the total impact of CO_2 emissions is the building industry, including new, maintenance, repair, and remodeling construction. Consider the building industry's share of total CO_2 emissions for all sectors of the U.S. economy:

- It's the largest sector accounting for roughly 20% of total annual industrial emissions and 7% of the U.S. annual total.
- Upstream CO_2 emissions are roughly 5 times greater than direct emissions (for construction of the building) and 10-20 times greater than the annual operation (use) of the building.
- Within the building industry, the largest single material or product contributing to CO_2 emissions is portland cement-based ready-mix concrete (9%).

For an office/academic type building similar in size and use to the NBSB Project - the baseline comparison building – upstream CO_2 emissions are associated with the various Uniformat Level 1 major building groups or sub-systems as follows (see Figure 2):

• Shell (Superstructure, Exterior Closure, Roofing)	24%
• Service Systems (Electrical, HVAC, Plumbing, Conveying)	22%
• Interiors (Interior Construction and Finishes)	15%
• Service Sector	14%
• Substructure (Foundations)	5%
• Equipment and Furnishings	3%
• Other/Miscellaneous	17%

PARTICUCULAR DISCOVERIES MADE SINCE THE FIRST REPORT

We now know or have a better handle on certain issues that were previously more uncertain. These include the following:

1) We now possess actual figures for the upstream CO_2 impact of recycled metal products
2) That at least one new material is now entered into the embodied CO_2 impact bar chart
3) That more high recycled content high CO_2 sequestering materials are now on the market
4) Due to problems encountered with fire regulations on the structural bio-composite wood components originally suggested, the scope of this possibility at the largest building scale is rendered less feasible.

This report identifies some areas where we can alleviate the global greenhouse effect, however small, at a smaller building subsystems or scalar level. Since we have little to go on relative to the new proposed design, we have decided to refine the definition of elements to be balanced without yet spending time on actual balancing.

The approach was to divide the building into individually identified scales that could be balanced within those scales before carrying burdens off to another scale above or below. These scales were the following from smallest to largest 1) interior office furniture system including minor partitions 2) the office including major partitions 3) at the floor level including halls, public rooms and vestibules, 3) At the whole building scale including exterior shell and building structure. These scales were coordinated to Uniformat categories as shown in the following chart.

METHOD REVIEWED

In order to define which materials are CO_2 sources and which are CO_2 sinks, the life cycle of the material must be analyzed. The general methodology relies on an accurate portrayal of two industrial processes occurring during the upstream life cycle stages of each material: the embodied energy used (i.e., fossil fuel consumption) and the physical and/or chemical processes utilized to transform materials. The data can be provided in terms of a) national use and production database per time period (usually annual) for a particular industrial process or b) in terms of energy consumption figures from a specific manufacturer for a specific material for a specific period of time. In the former case, assuming that both the fuel source and production technology are consistent within a particular industrial sector, the following data is required:

- the energy supply fuel source and quantity per unit weight for raw material acquisition and transport to all processing facilities of a particular industrial sector;
- the quantity of material produced by that industrial sector (e.g., steel) per unit weight per year (gross), or the quantity of material actually reaching the national building sector end use stage per unit weight per year (gross – exports = net);
- the amount of carbon stored (if any) per unit of material;
- the energy supply fuel source(s) and the quantity of fuel consumed per year by that particular industrial sector;
- the carbon intensity of each type of fuel source; and
- the physical/chemical CO_2 emission processes and quantity of emissions per unit of material output.

After the upstream CO2 emissions per unit weight of a material or product are calculated, then the carbon sink potential of the material, if any, must be identified. Among major building materials and products, only biomass materials are considered to have any carbon content. Trees, for example, can be as much as 53% carbon by weight. One pound of carbon contained in a biomass material is equivalent to the sequestering of 3.50-3.75 pounds of CO_2 from the atmosphere. A comparison of CO_2 upstream emissions to the carbon content of a long-life material yields a net CO_2 impact. Comparing the net CO_2 impact to the end use weight of a material yields a useful ratio for CO_2 balancing – a carbon dioxide intensity factor.

CO_2 INTENSITY FACTOR

The carbon dioxide intensity factor (CDIF) is defined here as the ratio between the net upstream CO_2 impact (emissions minus storage) of a material and the weight of the material. It can be described by the following equation:

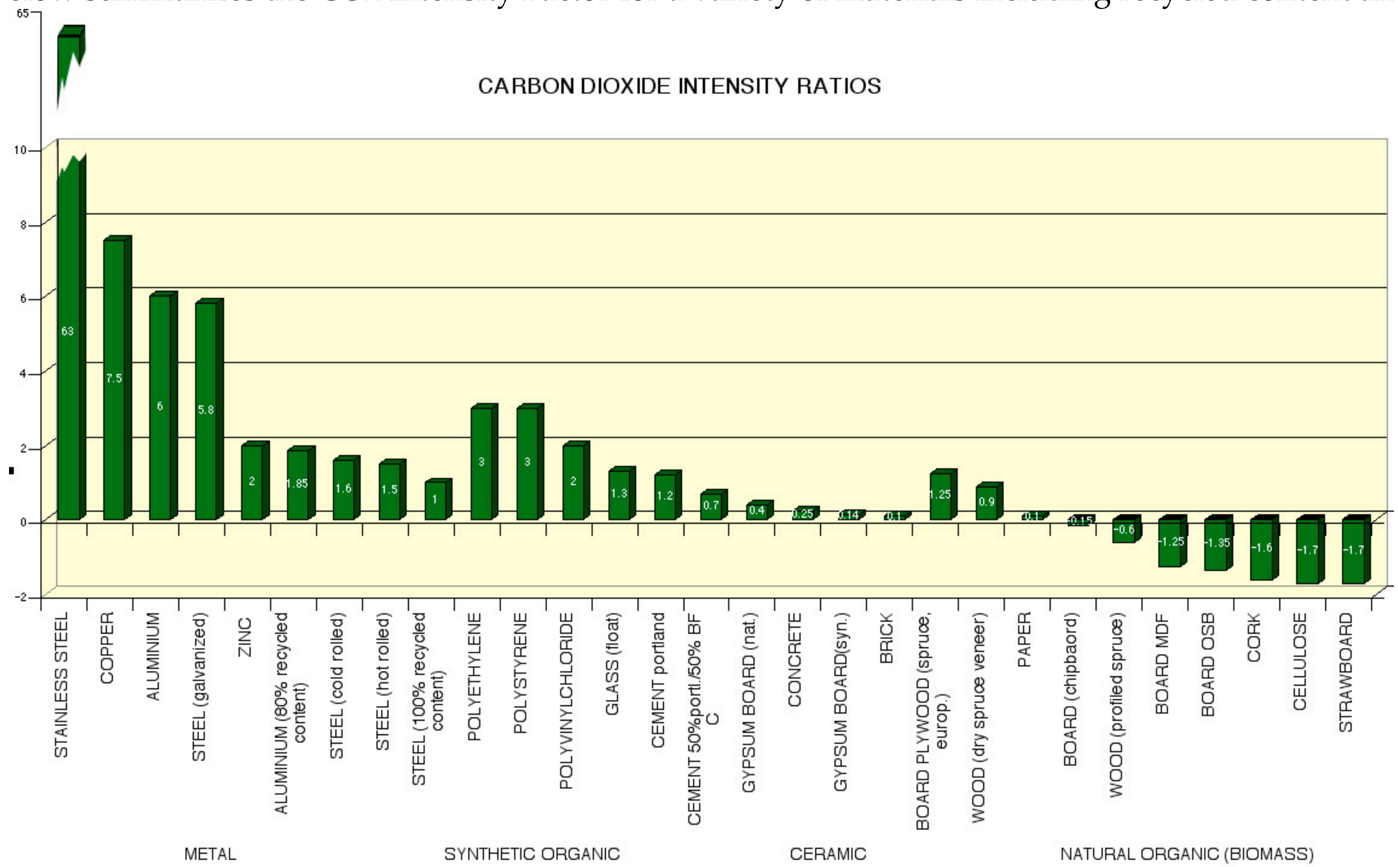
CDIF = $(CO_{2e} - CO_{2s})$/material end use weight,
where CO_{2e} = the weight of upstream CO_2 emissions,
and CO_{2s} = the equivalent weight of CO_2 stored as carbon in the mass of the material.

A material with a positive CDIF is a net CO_2 source and one with a negative CDIF is a net CO_2 sink. To illustrate the methodology, the derivation of CO_2 intensity factors for cement and particleboard is described in the Appendix. Cement is selected as an example of a CO_2 source material. It's production releases CO_2 from both fossil fuel combustion and chemical processes. Particleboard is included as an example of a CO_2 sink material.

The CDIF for fourteen common long-life building materials is shown in Figure 9. Metals are net sources of CO_2. In the case of iron and steel, for every pound used in buildings, roughly two pounds of CO_2 are emitted upstream. Therefore, CO_2 emissions are 2 times greater than the end use weight of steel in buildings and the CDIF is 2. By weight, synthetic organic materials such as polystyrene have a similar impact. Ceramic materials, on the other hand, emit much less CO_2. For every pound of concrete used in buildings, for example, slightly less than 1/50 (0.02) pounds of CO_2 are emitted upstream. Therefore, CO_2 emissions are 1/50 the end use weight of concrete in building and the CDIF is 0.2. By weight, the upstream impact of portland cement is much greater, having a 1.2 CDIF.

Most natural organic building materials and products, such as sawn timber and plywood, are net sinks of CO_2. For example, for every pound of sawn timber, lumber, plywood, or particle board used in a building, the net storage of CO_2 is 1/4–1/2 pound for the life of the building or product. Therefore, these materials have a CDIF of –0.25 to –0.5. This is a very rough approximation, for the actual CO_2 emissions that can be allocated to timber and fiber production vary greatly from region to region and depend on the source (e.g., tropical), management practices, and type of wood (e.g., softwood or hardwood).

This data indicates that metal, synthetic organic, and ceramic building materials are net sources of CO_2 emissions and that some natural organic or biomass materials are net CO_2 sinks. This is due to the capacity of biomass materials to absorb carbon dioxide and transform it to carbon in the mass of the material. The relative impacts of one material compared with another in terms of CO_2 released or absorbed is information that is relevant to addressing the Kyoto Protocol agreement. Consider, for example, the design goal of a CO_2 emission "low-impact" building. The design process would include an analysis of the overall balance between CO_2 source and CO_2 sink materials. Specifications could state CO_2 balancing as a performance criteria for individual products or groups of products and building systems such as exterior closure or structural frame. For example, a reinforced concrete structure may be chosen over an all-steel structure because it achieves a better CO_2 balance, assuming that the volume of steel in the former is much less than in the latter. The chart below summarizes the CO_2 Intensity Factor for a variety of materials including recycled content and stainless .



CO_2 BALANCING APPLIED TO OPEN BUILDING FROM THE OFFICE COMPLEX DOWN TO OFFICE FURNITURE

Since the final building configuration is unknown at this time, tconcentration has been placed onto a generic Interior and Finishing Systems The following diagrams represent the various subsystem components at the Interiors Sub-system and Furnishing Sub-system scales. These scales correspond to the Interiors and Equipment/Furnishings major group Level 1 in the Uniformate system. Interiors includes the movable partitions and raised floor systems while Furnishings includes portable office furniture and portable office furniture partitions when they function in modular coordination with the furniture system. Each system is organized around two major specification areas according to open building system criteria one structure and the other infill. A third category referred to as method is also identfied so that certain specific criteria such as physical connections are placed within a performance criteria standard. These standards include such things as connection or modularity criteria.

FUNITURE SYSTEMS

MATERIALS

STRUCTURAL

-High recycled content light weight partition systems.

-High recycled content light weight structure system.

-High recycled content light weight desk support.

INFILL

-Partitions-Biocomposite-solid/hollow core/surface

-Shelves-Biocomposite

-Desk tops-Biocomposite

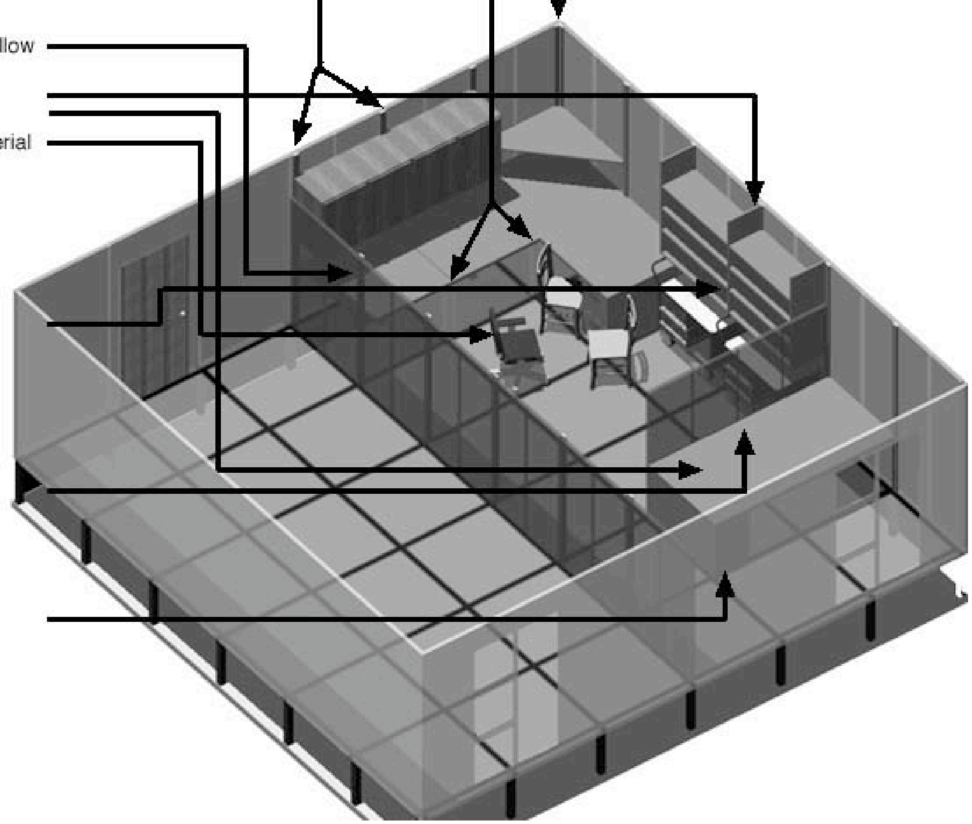
-Chairs-Natural fiber/Natural material

METHODS

-Modular coordinated removeable shelves

-Modular coordination between partitions and furniture

-Modular coordination between funiture (desks) and floor systems (utilities)



MAJOR PARTITION SYSTEMS

MATERIALS

STRUCTURAL

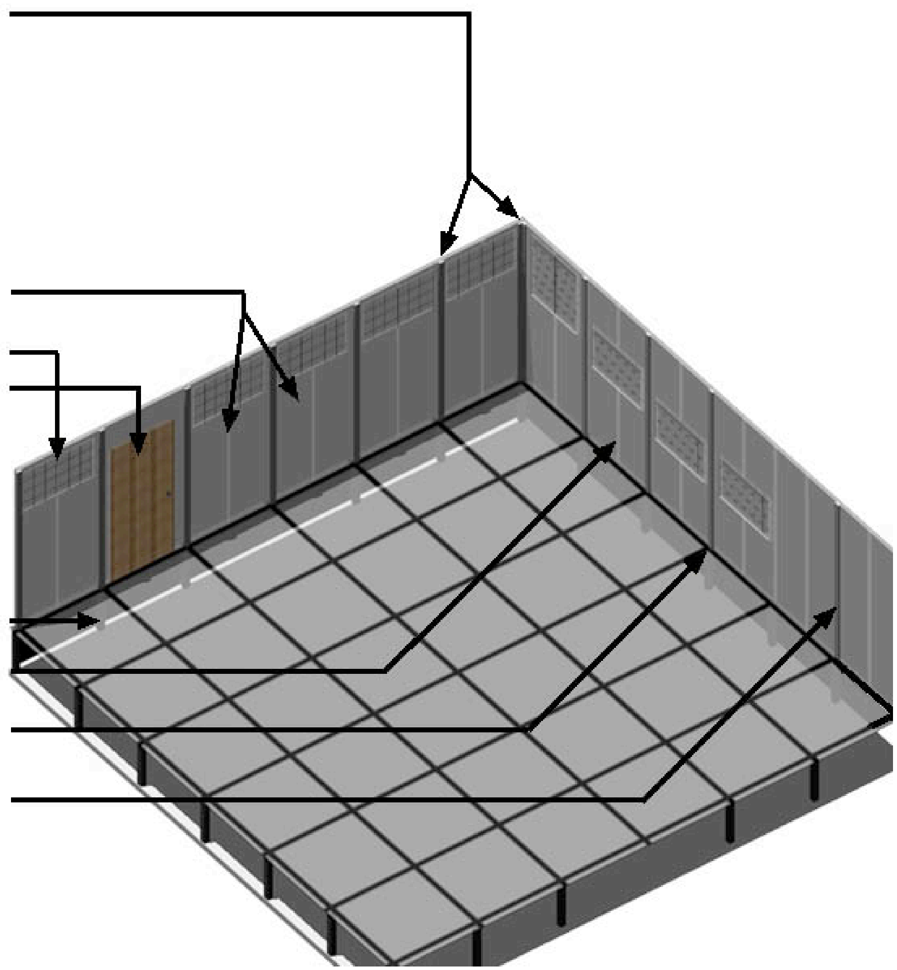
-Structural frame-high recycled metal content

INFILL

-Dense biocomposite (partition/door)
-Glass-high recycle content
-Doors-solid core biocomposite

METHODS

-Flexible modular system
-Smaller modules to ease user interaction
-Modular walls match raised floor system
-Embedded utility cores



FLOOR AND CEILING SYSTEMS

MATERIALS

STRUCTURAL

CEILING

-High recycled content metal structural components

FLOOR

-High recycled metal support

INFILL

CEILING

-Biocomposite ceiling panels

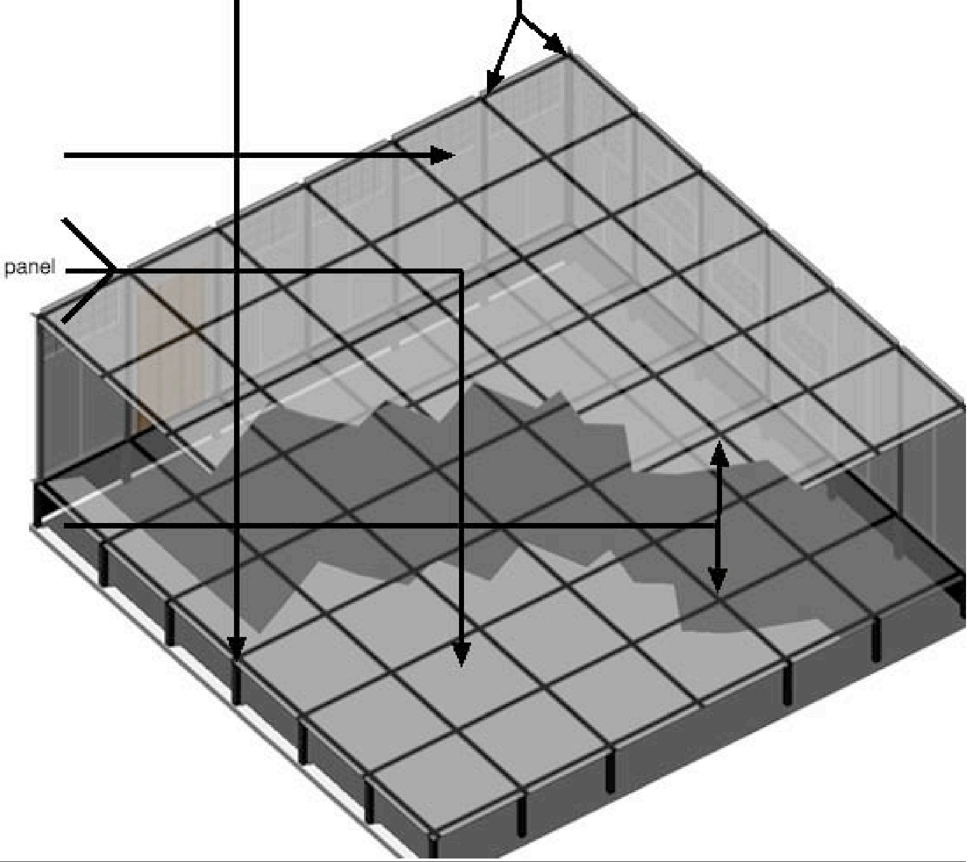
-Sealed surface

FLOOR

-Biocomposite/natural flooring surface

-Biocomposite/natural flooring panel

-Biocomposite/natural flooring sub-surface



METHODS

-Modular coordination between floor/ceiling system

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APPENDIX

APPLIED CO2 BALANCING USING A HYPOTHETICAL INTERIORS AND FURNISHINGS SUB-SYSTEM

The Interiors and Furnishings Sub-Systems include three Level 2 group elements – Interior Construction, Interior Finishes, and Furnishings. The CO_2 life cycle balancing effort for these sub-systems explores the possibility of designing "zero-impact" interior partitions, finishes, and furnishings. If significant amounts of carbon from atmospheric CO_2 can be stored semi-permanently in a building's interior elements, then perhaps the amount of CO_2 sequestered can be equal to or greater than the amount of CO_2 emitted during the upstream stages of the life cycle of building interior materials and products.

To explore this possibility, the carbon source/sink ratio of three simplified furnishings will be analyzed. Each furnishing will be composed of only two materials. The structural frame of each furnishing is steel, a net carbon source, while the infill materials - all desk tops, shelves, and enclosure panels - are natural organic products, net carbon sinks. The infill materials selected are high in biomass content, such as softwood lumber, particleboard, and straw panels. In addition, the design of a “zero-impact” movable interior partition will be explored.

The analysis of “zero impact” furnishing units will use three simple models: a) a shelf unit, b) a cabinet unit, and c) a desk unit. Each unit is made of a steel frame (a net CO_2 source) and natural organic panels (net CO_2 sinks). Using the figures and method described in the Building System chapter, each type of furnishing unit will be designed for CO_2 balance. Namely, how much (by weight and volume) infill material of high biomass content will be required to result in a condition where the carbon source equals the carbon sink within the boundary of the furnishing unit?

Shelf Unit

Assume a steel frame shelf unit that is 4’ long, 1’ wide, and 2’ high with three 4’x1’ shelf panels. The total length of the steel members is 10 feet (120 in.). If the thickness of the steel pipe is 1/16”, then the cross sectional area of each steel member is 0.185 square inches yielding a total volume of steel of 22 cu. in. or 0.013 cubic feet. The volume of softwood infill materials required to balance the CO_2 of the steel frame is 120x(0.013 cu. ft.) which equals 1.54 cubic feet. The total surface area of the three shelves is 12 square feet. Therefore, the thickness of each shelf must be 0.13 feet (1 1/2”) to provide 1.54 cubic feet of infill material.

Cabinet Unit

The same method can be used to explore the case of a cabinet unit. Assume a steel frame floor cabinet that is 2’ long, 2’ wide, and 5’ high with three 2’x2’ shelf panels and three 2’x5’ side panels. The total length of the steel members is 32 feet (384 in.) yielding a total volume of steel of 71 cu. in. or 0.04 cubic feet. The volume of softwood infill materials required to balance the CO_2 of the steel frame is 120x(0.04 cu. ft.) which equals 4.93 cubic feet. The total surface area of the three shelves and three side panels is 42 square feet. Therefore, the thickness of each shelf and side panel must be 0.117 feet (1 1/2”) to provide 4.93 cubic feet of infill material.

Desk Unit

For the desk unit, the steel frame is 4’ long, 2’ wide, and 5’ high with one 4’x2’ desktop panel, three 4’x1’ shelf panels, and two 4’x2’ back panels. The total length of the steel members is 32 feet (384 in.) yielding a total volume of steel of 71 cu. in. or 0.04 cubic feet. The volume of softwood infill materials required to balance the CO_2 of the steel frame is 120x(0.04 cu. ft.) which equals 4.93 cubic feet. The total surface area of the desktop, three shelves, and two back panels is

36 square feet. Therefore, the thickness of each shelf and side panel must be 0.14 feet (1 5/8”) to provide 4.93 cubic feet of infill material.

Partitions and Finishes

An interior non-bearing partition is typically 4’ wide by 8–10’ high with the thickness varying with each application. Assuming a 4’x8’ partition mounted in a continuous steel frame like the one described above yields a total length of steel of 24 feet (288 in.). The volume of steel is 53 cu. in. or 0.031 cu. ft. and the corresponding volume of infill material is 3.67 cu. ft. The area of the partition is 32 sq. ft. resulting in a panel thickness of 0.115 ft. (1 3/8”).

Natural organic wall and floor finishes can add to the CO_2 sink potential of building interior systems. Some of these materials are wood and cellulose paneling, paper, hemp, and burlap wall coverings, and wood and grass flooring. Many of these are low-density materials and are manufactured in very narrow thicknesses. Their contribution to the CO_2 sink function of interior elements has therefore been omitted.